as accidental. One of his proofs of this claim is that a certain statistical index, which may appropriately be called Goutereau's ratio,[28] has the small value of 0.97 for the numbers in their natural order of succession, whereas theory shows this ratio should have the value $\sqrt{2}$ or 1.41 for a wholly unrelated sequence of the numbers.

This is a very important point, and in order that each reader may understand and appreciate the full force of this argument we shall carefully define what Goutereau's ratio is. Every one knows that the algebraic sum of the *departures* of any group of numbers whatever from the *mean* or *average* is zero. The sum of all the departures *regardless of sign* divided by the number gives the *average departure* or *mean deviation*, a statistical index which is, like the mean itself, wholly independent of the order of succession.

Now to base any claim or argument upon a particular order of succession of a given set of numbers we must have a suitable measure or statistical index, depending upon the order of succession alone. Happily this index is the *mean variation*, *v*. In any irregular sequence of numbers a, b, c, d,- - - -x, form the consecutive differences b–a, c–b, d–c- - - - - - a–x.[29]

As in the case of the departures from the mean, we find that the *algebraic* sum of all the variate differences, if taken in a ring, is zero. The sum *regardless of sign* divided by the number of values is the *mean variation*, which is the index for the order of succession we desire, and resembles and may be compared with the unchanging index afforded by the *mean deviation* of the same numbers regardless of order of succession.

Goutereau, with the aid of Maillet, has shown that the ratio $v \div md = 1.41$ for Gaussian numbers in fortuitous order of succession. Thus we have a very valuable index which closely relates the order of succession to the mean deviation of the same numbers.

With this explanation of Goutereau's ratio, each reader should easily appreciate the significance of what follows.

Referring again to Figure 6 the natural order of the 61 numbers with its ratio of 0.97 appears at A. From arithmetic we find there are more than 21×10^{41} possible different sequences. Two of these, arbitrarily set up to show the minimum and maximum Goutereau ratios, are shown at B and C. The 61 numbered disks were placed in a small bowl and from 10 separate drawings 10 values of the Goutereau ratio were computed, yielding an average value of 1.36. The lowest value was 1.24, the highest 1.51. One sample drawing is shown at D. The smallness of the value 1.36 as compared with 1.41 may or may not be significant. It seems that 10 drawings should be expected to give an average value of the ratio very close to 1. 41, but it is probable in the present case that the original 61 numbers depart sufficiently from a Gaussian distribution to explain the relative smallness of the average of the 10 drawings.

The graph at E shows one result of personal control and bias in intentionally setting up a periodic sequence as far as the numbers themselves permit, giving the low ratio 0.81.

It seems utterly improbable that any fortuitous sequence could give the natural order of succession with its low ratio 0.97 any more than chance drawings could produce the selected orders of succession B and C, giving respectively the minimum and the maximum values of the ratio, or even the sequence E with its ratio 0.81.

The claim that the natural sequence of the numbers is a controlled sequence and not an accidental one can not be brushed aside either because a physical explanation of the control is wanting or without refuting or offering some better interpretation of the evidence than the foregoing, which deals with but a fragment of the whole body of data, correlations, etc., submitted by Mr Clough.

To conclude this brief note, we must recognize that in its present form we are undoubtedly dealing with a very complex feature of periodicity, probably made up of two or several elemental forms. It is well known that two periods differing slightly in length, one with large amplitude and the other with small, yield a composite period which appears to change its length systematically. Quite an extended examination on my part of data by the Fourier analysis gives little hope of explaining the observed facts in that way. A large number of elemental periods always appear to be necessary to even approximately represent the observations. Nevertheless, the subject has by no means been adequately investigated and is entitled to the serious attention of students and critics alike.

[28] See footnote no. 14, ante.

[29] By including the last term (a–x) we literally assume that the numbers constitute a closed system as if in a ring. This also causes the number of variate differences to be the same as the number of values, also the same as the number of departures from the mean. If the difference a–x is *not* included, the number of variate differences will be n–1 for n observations, and other technical inconsistencies arise which become inconsequential, however, when n is very large, which, on the other hand, is seldom the case. Therefore, we prefer to analyze all these cases as if the observations constituted a closed ring or system.

VAN BEMMELEN ON THE INTRATROPICAL PART OF THE GENERAL CIRCULATION OF THE ATMOSPHERE

551.513 : 551.55

By B. M. VARNEY

(Weather Bureau, Washington, September 25, 1924)

Dr. W. van Bemmelen in a recent paper in the Meteorologische Zeitschrift[1] makes one of the most import contributions to the study of the general circulation of the atmosphere that has appeared in recent years. During the years 1909–1917 at Batavia a total of 869 pilot-balloon flights were carried out, most of them being observed by double theodolite.[2] Doctor van Bemmelen has previously discussed the Batavia observations and offered tentative explanations for the phenomena observed.[3] His paper here summarized extends and somewhat revises his former views. Correlated with the results of the balloon flights as the basis for his discussion is evidence as to the intratropical circulation deduced from cirrus movements in the region.

Method of summarizing the data.—The author takes care to point out that the paucity of observations from the higher levels renders interpretation of the conditions there somewhat doubtful, and then states his method as follows:

> For each level and each month the north and east components of all observed wind vectors were combined and the means computed. With the aid of these means two isopleth diagrams were constructed, one for the north component and the other for the east, using altitudes as ordinates and months as abscissæ and from them the mean directions and velocities were computed. Such procedure is obviously justified where constancy of direction of the air streams is a notable feature.

For the purposes of this note, the writer has translated the results of the above procedure from van Bem-

[1] Volume 41, 1924, no. 5, pp. 133–141.

[2] Results of the observations are dealt with in Transaction Nos. 1 and 6 of the observatory.

[3] Proc. R. Acad. of Sciences, Amsterdam, Apr. 26, 1918. A paper by W. van Bemmelen and J. Boerema, "Horizontal oscillation of the free atmosphere up to 10 km. at Batavia," published in Proc. K. Akad. Amsterdam, 1917, vol. 20, pp. 119–135, was abstracted in Science Abstracts, Sec. A, Nov. 30, 1917, No. 1235, this abstract being reprinted in the MONTHLY WEATHER REVIEW, January, 1918, 46: 22. See also van Bemmelen, W., "The antitrades," MONTHLY WEATHER REVIEW, 1922, 50: 90–91, reprinted from Nature, Feb. 9, 1922, pp. 172–173, and brief discussion of this paper by Shaw, W. N. in same REVIEW, p. 92, reprinted from Nature, Feb. 16, 1922.

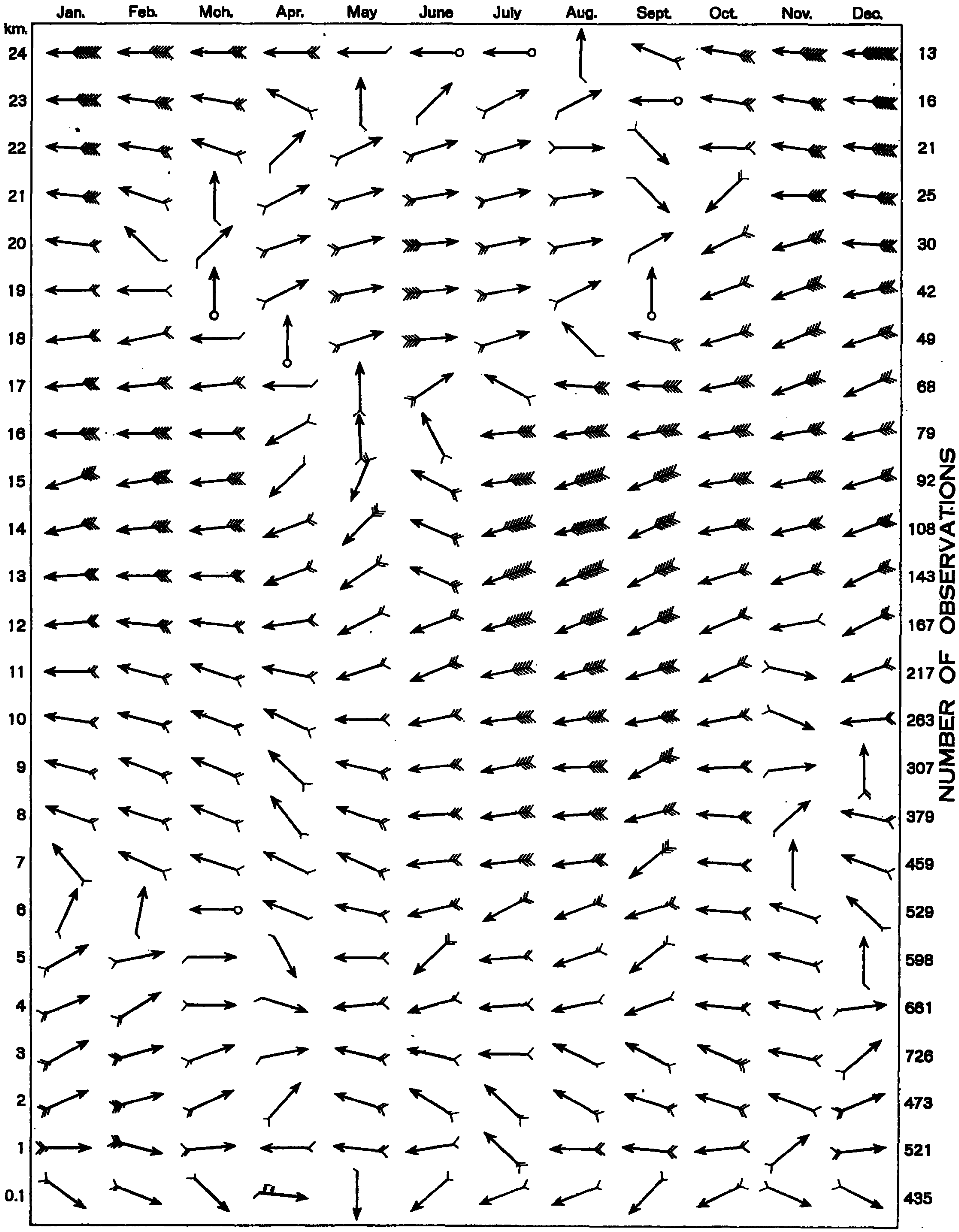

FIG. 1.—Mean wind directions and velocities over western Java, based on van Bemmelen's Table 1 in Met. Zeit., May, 1924, p. 134. Arrows fly with the wind. Velocities in m. p. s., each feather equaling 1 m. p. s. At 10-km. altitude and below, tenths of a m. p. s. are approximately represented by the fractional lengths of a feather

melen's table into graphic form (fig. 1) that the great seasonal shifts of the air streams over western Java may be more clearly visualized and a comparison made easy with his map showing conditions at the cirrus level.[4] In this figure, north being at the top and east at the right, the arrows fly with the wind, and mean velocities in meters per second are shown by the number of feathers (a feather to each m/s) on the arrows. Below 10-km. altitude, velocities were carried out to tenths of a meter per second, and these tenths have been approximated in the fractional lengths of a feather.

Several major air streams are distinguished:

1. At the earth's surface the west monsoon from November to April.
2. At the earth's surface the east monsoon during the rest of the year.
3. Above these streams, a current from points between east and southeast, persisting throughout the year, and designated as the trade wind.
4. Above the trade, a deep current flowing from points largely between east and northeast, persisting throughout the year, to which the name pseudoantitrade is provisionally applied.
5. Above this antitrade a reversion to winds from directions south of east at certain altitudes and times of year, the upper trade wind.
6. At the upper limit of observation an east wind, persisting through nine months of the year, though of high velocity for only about half the year, designated as the Krakatoa wind.
7. Above the antitrade also, during a part of the year, a west wind with components of motion from the south, called the high-altitude west wind.

Before summarizing Doctor van Bemmelen's discussion and explanations of the different currents, attention may be directed to Figure 2, in which for five representative levels the annual march of wind velocities has been plotted. By varying the characters of the lines it has been possible also to show every important change in the régime of the winds, except for the east monsoon, which will be seen presently to be but a local manifestation of a much more important stream, and excepting also the base of the west monsoon, the main flow of which is better represented by conditions in the 2-km. level. Brief note may be made of the following points:

The 2-km. level.—Alternation of west monsoon and the southeast trade, the trade riding above the monsoon (see curve for the 10-km. level) from November to April, inclusive, but descending into the same level as the west monsoon during the Southern Hemisphere winter.

The 10-km. level.—Alternation of the trades (January to April, inclusive) with the antitrades (May to December, but interrupted in November by the unexplained westerly winds).

The 15-km. level.—Continuous antitrade throughout the year except in June, when it is changed into a wind from the east of south. This change is apparently due to friction with the overlying high-altitude west wind, since the same type of change occurs also in the 16, 17, and 18 km. levels during May to September. It will be noticed that the depth to which the influence of the west wind penetrates changes simultaneously with the changes of altitudes of the bottom of the west wind.

The 20-km. level.—Three great streams at different times of the year occupy this level. The basal portion of the upper trade descends to it during January-February; the heart of the high-altitude west wind at its greatest velocities is found here from March to September, inclusive, and with the dying out of this wind it is replaced during October and November by the antitrade, which in those months reaches its maximum altitude (21 km. plus in October). In December, the east wind at this level appears to be merely the mean effect of the antitrade below and the upper trade above, and it soon gives way to the upper trade, which is seen continuously to extend the depth of its influence through the period September to January, inclusive.

The 24-km. level.—Three currents also in this level: the Krakatoa wind for eight months, an unsettled condi-

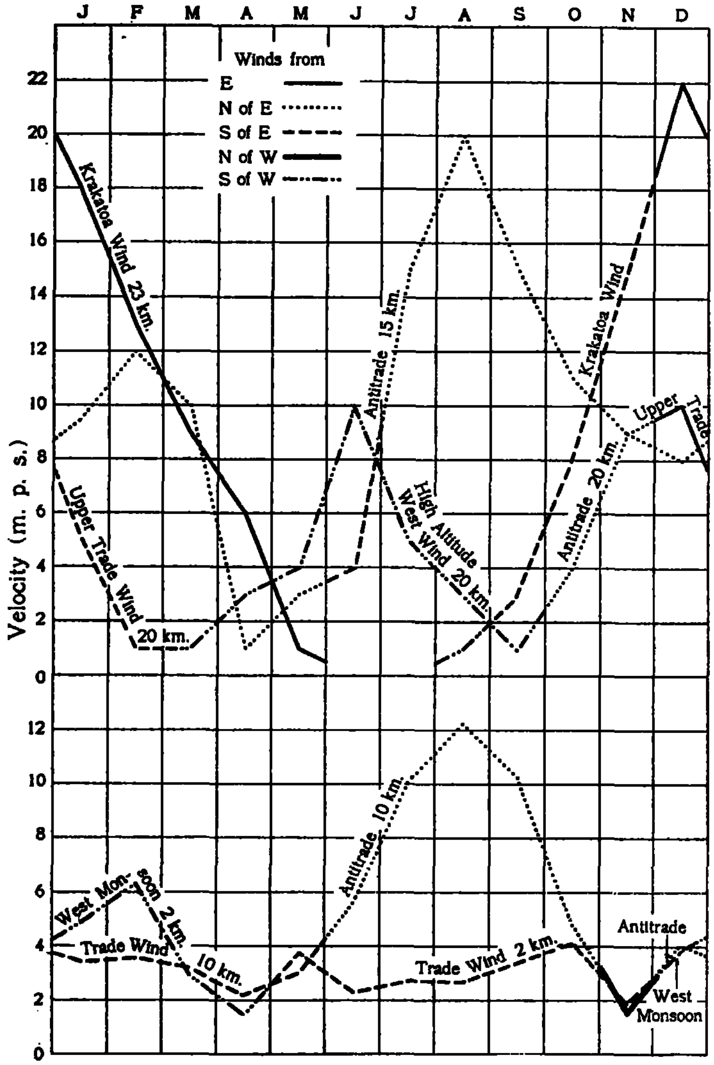

FIG. 2.—The annual march of wind velocities at five levels over western Java

tion in August, and the upper trade wind in September, October, and November. The Krakatoa wind is seen in June and July to be largely neutralized by the high-altitude west wind.

Comparison of Figures 1 and 2 emphasizes the fact that the seasonal changes of altitude of the different streams is so great that at no single level does the same wind blow throughout the year. Perhaps the most striking result of these changes is seen in April and May, when at many levels the transition from one régime to another takes place, and wind velocities consequently are in general relatively low and direction variable. This slackening of activity obviously corresponds with the reversal of the monsoon occurring in the lower 3 km. in those months.

[4] Reproduced from the MONTHLY WEATHER REVIEW.